MODIS SCIENCE TEAM MEMBER
Semi Annual Report (January - March 1995)

Chris Justice (University of Maryland)
Eric Vermote (University of Maryland)
Jean-Claude Roger (University of Maryland)
Luke Flyn (University of Hawaii)

Contract#: NAS5-31365

a) Task Objectives

The objectives of this phase of the project were: to continue the research program developing the 'at-launch' algorithms for MODIS atmospheric correction, vegetation indices, fire detection and land cover and to build the infrastructure and collaboration to permit the research to be undertaken. The completion of the ATBD revisions and the development of the beta code were given a high priority. The project has developed a number of collaborative projects which are intended to expand the scope of the team members activities and involve a larger community in the MODIS research. Due to the small number of researchers addressing the issues necessary for the methodological advances needed for MODIS, emphasis has been given to developing collaborative research and MODIS outreach through the IGBP Data and Information System Core Project. In addition, the goals of the MODIS project, the status of the instrument and preliminary results of the research were presented at key scientific meetings. The project was also represented at the MODIS Team meeting. Results of the studies undertaken as part of the project are in the process of being written up and submitted for publication.

Ist Quarter: January - March 1995

b) Tasks Accomplished (Data analysis and interpretation)

Specifically the project has addressed the following topics over the last three months:

MODIS Atmospheric Correction:

Modis Beta Delivery: A beta code of MOD09 has been delivered to SDST as well as a test dataset (mas data and synthetic data). SDST started integrating the SDP Toolkit into this code.

6S: A routine to compute the physical properties of a mixture of aerosol types has been introduced into the 6S code. This routine allows the users to consider a mixture of particles originating from different sources (5 max). It also allows the user to directly enter the size distribution derived from combination of satellite and sunphotometer measurements.
Following a meeting held at the Laboratoire d'Optique Atmospherique in Lille in February, a final version of the paper describing 6S has been completed.

MODIS Airborne Simulator:

Atmospheric Correction Validation:

Sunphotometer Network: A proposal to NASA on LTER Atmospheric Correction has been approved and funded. This will augment the MODIS activities with respect to algorithm validation. TM data is being selected associated with sunphotometer measurements. 5 sites have been selected (Hog Island, HJ Andrews, Bonanza Creeks, NTL and Sevilleta).

A proposal was submitted to the "VEGETATION International Users Commitee" and was accepted and travel to meetings was funded. The proposal entitled "VEGETATION Instrument and MODIS: a joint research and development project on terrestrial monitoring" (with E. Vermote as P.I., and J.C. Roger, C.O. Justice and C.J. Tucker as Co.I's.) will provide VEGETATION with methods for calibration and atmospheric correction developed by the investigators. This will enable methods to be explored for the MODIS instrument due for launch 1 year after VEGETATION. The opportunity for the MODIS team to test algorithms on a global data set using the blue channel available on VEGETATION is a unique aspect of this proposal.

MODIS Land Cover:

Justice and Vermote attended the MODLAND working group meeting on BRDF, VI, Atm. Corr and LAnd Cover at Boston University.
The Modis Land Cover Test site initiative is procee

MODIS Fire Detection:

Luke Flynn completed the first cycle of activity with this project and submitted his final report. (Appendix A).

MODIS Vegetation Index:

The NDVI and MVI were incorporated with the atmospheric correction code in the Beta Code delivery to SDST.

c) Data / Analysis / Interpretation

- Continued analyses of AVHRR, MAS and Landsat TM data were performed as part of the MODLAND prototyping effort.
- Work was started to develop the Beta Delivery Code and test data sets planned for delivery in early November. The Code will be based on the MAS data for testing and will include the Code to derive vegetation indices.

Meetings Attended

Justice presented results of the fire detection capability of existing sensors and the improved performance of the MODIS sensor at the AGU Chapman Conference in Williamsburg on Fire In the Environment.
A presentation was made by Vermote at the "MODIS Land Cover, BRDF/Albedo, and surface Reflectance Workshop" held in Boston in January. A report of the correction scheme (modeling and sensitivity studies using simulated data) was shown.
A presentation was made by Vermote during a meeting of co-investigators of remote sensing of aerosols by POLDER in Lille in February. The atmospheric correction scheme proposed for MODIS was presented to the POLDER community.
A presentation on "atmospheric correction in the visible and near infrared for present and future sensors" was made during the "Remote Sensing Science Workshop" at the GSFC.

f) New Papers

Vermote, E. F., ElSaleous, N. Z., Kaufman, Y. J. and Dutton, E., Stratospheric aerosol perturbing effect on the remote sensing of vegetation: Correction method for the composite NDVI after the Pinatubo eruption. (Submitted in March to special issue of RSE).

Roger, J. C. and Vermote, E. F., Computation and use of the reflectivity at 3.75mm from AVHRR channels. (Submitted in March to special issue of RSE).

Vermote, E.F., and Kaufman, Y.J., Absolute calibration of AVHRR visible and near infrared channels using ocean and cloud views. (Submitted in Feb to Int. J. Rem. Sens).

Justice, C.O., Kendall, J., Dowty, P., and Scholes, R. J., Satellite remote sensing of fires during the SAFARI Campaign using NOAA AVHRR data. (Submitted to JGR)

Scholes, R.J., Ward, D., and Justice, C.O., Emissions of trace gases and aerosol particles due to vegetation burning in Southern Africa. (Submitted to JGR)

Huete, A., Justice, C.O., and Liu, H., Development of Vegetation and Soil Indices for MODIS. R. S. Env 49: 224-234.

APPENDIX A - Final Report by L. Flynn (Univ. Hawaii)

Final Report: MODIS Fire Test Maps From Remotely Sensed Data

Effective Dates: September 15, 1994 - February 28, 1995

PRINCIPAL INVESTIGATOR:
Luke Flynn
Hawaii Institute of Geophysics and Planetology
SOEST
University of Hawaii, 2525 Correa Road
Honolulu, HI 96822
(808)956-3154

AMOUNT RECEIVED: $24,105
TIME PERIOD: 5.5 months

MODIS Fire Test Maps From Remotely Sensed Data

ABSTRACT:

The principal objective of this work was to produce a useful simulated MODIS test data set to use as a test for the Fire algorithm developed under the guidelines in the MODIS Fire ATBD written by Chris Justice and Yoram Kaufman. While this investigator found AIRDAS data of fires to be unsuitable for the purpose of creating test data sets due to noise problems, he was able to create a 3.95 µm MODIS band from TM data and then convert that data to MODIS spatial resoltuon using a program supplied by Kai Yang at Goddard SFC. The IDL program used to create the 3.95 µm data set is detailed below. Additionally, the investigator served as a Mission Scientist for the SCAR-C deployment (which lasted for 3 weeks of this contract). Attempts were made to collect spectra using a ASD spectrometer, but unfortunately, the results were less than useful.

MODIS Fire Test Maps From Remotely Sensed Data: Final Report

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I. Statement of Completed Effort

I.1 Introduction

This report will begin by reviewing the proposed objectives before going into the specific findsings of each part of teh proposal. The funded contract could basically be broken dwon into two sections: SCAR-C and MODIS Test Data sets. The results of the proposal investigations will be given below and will be preceded by a short statement of what the proposed objectives were at the beginning of the contract.

I.2 SCAR-C

The proposed objectives for SCAR-C were as follows:

A) Provide technical expertise (high temperature thermal anomalies)

B) Serve as the Mission Scientist for the days when Drs. Yoram Kaufman and Lorraine Remer could not serve in that capacity.

C) Provide ground-based field data of burned areas using the 1600-channel, 0.4 - 2.5 µm University of Hawaii FieldSpec FR system.

The SCAR-C mission was a great success from the standpoint of the number of images of wildfires and prescribed burns collected with the ER-2 and the sampling done by other airborne and field teams. Wildfires and prescribed burns were observed in 4 states (California, Oregon, Washington, and Idaho). While generally small (≤ 100 acres), prescribed burns afforded the opportunity to make airborne measurements before the fire was set, during the flaming stage, and the post-flaming stage. During one exceptional set of flights, the ER-2 completed 9 passes over the Quinault (Fig.1), Simpson, and ITT burns, which were all located in southwest Washington state. The ER-2 arrived before the Quinault fire was lit and remained overhead or the duration of the burn acquiring MAS and AVIRIS data every 10 - 15 minutes. This will provide an exceptional data set to study fire development for this particular fuel type.

While wildfires were more difficult to predict, the data acquired from them is perhaps a more realistic assessment of fire development with time. We were very fortuante to be able to observe a number of fires, including the Chicken Complex (SE Idaho, ~250,000 acres) noted for large areas of burn scars and very distributed fire cells; the Barkley fire (central California, 6,000 - 10,000 acres) which flared up to nearly twice its size on one day and which we were able to observe on numerous days as it was generally in the flight route of the ER-2 to the other fires; and the Specimen Creek fire (Fig.2, northern California, ~5,000 acres) which was so intense on two days that the ER-2 pilots reported noticeable convection cells above the fire (on these days, fire fighters were pulled away from the fire, which was considered too dangerous because of high winds).

Lorraine Remer, Yoram Kaufman, and this investigator shared the duties of Mission Scientist during the SCAR-C experiments. Our primary tasks were to coordinate the efforts of the project given all the available information on fires. The entire effort was handled in a very professional manner with all 3 Mission Scientists performing all of the tasks at one point or another.

An attempt was made to use the Analytical Spectral Devices, Inc, FieldSpec FR spectrometer to collect data at a prescribed burn. Having a background in physics, this investigator believes that it is very important to understand the complete picture of fires, especially during the flaming stage. This will even be important when extrapolating information to the 1-km scale of MODIS. If we can understand or categorize fire temperatures and burn scar temperatures as a function of time, we may be able to estimate the amount of fuel consumed within a given time period of hwne the MODIS instrument collected the data. This author has no previous experience measuring fire temperatures, but does have extensive experience measuring high temperature volcanic phenomena (Flynn and Mouginis-Mark, 1992; Flynn et al., 1993; and Flynn and Mouginis-Mark, 1994). The lessons gained fom spectral measuremenst of high temperature phenomena can be considerable at all scales. An experiment to meaure the reflectances of grass, shrubs, and trees was attempted at Jasper Ridge in California. Unfortunately, problems with the spectrometer (integration time) made the project unsuccessful. An attempt was made to be at a prescribed burn near Tillamook, OR, but that was also unsuccessful owing to strong, erratic winds above the target area. The burn was cancelled for the day.

I.3 MODIS Test Maps

The objectives of the MODIS test data study are as follows:

A) Provide realistic simulated MODIS data based on remotely sensed fire data.

B) Determine the suitability of AIRDAS data and Landsat TM for this purpose.

C) Generate 1 km spatial resolution pseudo-MODIS images in the 1.6, 2.1, 3.95, and 11 µm channels using relevant data sets (AIRDAS, TM) coupled with field measurements from SCAR-C.
D) Use the ouput created to test the MODIS fire algorithm detailed in the MODIS Fire ATBD.
E) Suggest modifications to MODIS Fire algorithm, if necessary, in response to tests.

The MODIS Fire algorithm requires realistic data to test and fine tune it. The key to the Fire algorithm is the 3.95 µm band, chosen for its spectral location at a low response from reflected sunlight sources and a low response from low-temperature heat sources such as the thermal background). The two candidiate data sets which this investigator looked at using were the AIRDAS data set flown in Brazil by Jim Brass and Landsat TM data acquired of the Yellowstone National Park fires on 9/8/88. While AIRDAS offers many features that could potentially be extremely important to producing a MODIS map, the instrument was found to still be in a developmental stage. The Landsat TM offered a better alternative but also had drawbacks, mainly associated with the saturation of the instrument detectors. The advantages and disadvantages of each are detailed below.

I.3.1 AIRDAS Noise Problems

The AIRDAS instrument is a 4-channel airborne radiometer developed by Jim Brass and Robert Higgins of the NASA Ames Research Center. AIRDAS was designed to be flown by medium altitude aircraft and has been deployed on a number of twin-engine airplanes as well as the NASA Lear jet. The instrument has a number of engineering advantages over other sensors including rapid deployment time, easily shipped, can be flown on a variety of aircraft using aircraft power sources. However, the major advantage of using AIRDAS to study fires is that the four channels of the instrument do not saturate from emitted radiance. This is probably the only instrument in the NASA inventory for which this claim can be made. This means that even extremely hot fire cells associated with firestorms will not saturate the instrument's detectors. A negative result of this is that the images appear very dark (even for daytime acquisitions), because the dynamic range of the instrument is so great. "Stretching" areas of the entire dynamic range can partially correct for this effect.

The 4 AIRDAS channels are located in the red-visible (0.7 µm), the near-IR (1.5 - 1.7 µm), the mid-IR (3.95 µm, also known as the fire channel), and the far-IR (10 - 12 µm). Filters can be used to narrow the spectral ranges of the detectors. The instrument was designed to measure fires as the placement of the spectral channels is optimal for this purpose. From a radiative temperature standpoint (as opposed to the smoke and aerosol viewpoint), the band placement is optimal because the 0.7 µm cahnnel is used to locate the fire. The 1.5 - 1.7 µm channel will be especially sensitive to strong fires, since the sources will have to be radiating at high temperatures to be measured in this wavelength range. As mentioned above, the 3.95 µm channel is particularly useful as it is located in a spectral region where interference from reflected sunligth and the thermal background are at a minimum. In addition, this spectral region would be sensitive both to flaming fires (~800 - 1000°C) and smoldering fires (~300 - 400°C). Lastly, The 10-12 µm channel could be used to monitor burn scar temperatures. It would be most sensitive to chnages in the thermal background or sources <100°C.

If AIRDAS worked as well as it was planned in the design stage, it would be the best tool to measure fire temperatures. The fact that the band placement is optimal and the channels do not saturate means that one should be able to uniquely solve the two-blackbody problem with the 3 infrared channels. However, the main reason why the AIRDAS was determined to be not useful for producing MODIS data sets was due to the instrument noise of the mid- and far-IR detectors. For unknown (to this investigator) engineering purposes, the last two detectors are "sandwiched" meaning that they are layered one on top of the other. Unfortunately, to measure useful radiances with the 3.95 µm channel, one must use a narrow bandpass filter (3.95 - 4.02 µm, roughly). While this is supposed to correct the mid-IR channel, in this configuration, the far-IR channel does not receive enough emitted radinace to amke the data useful. Figure 3 shows AIRDAS data of the Greenmeadow fire in California. The streaks on the color image can be traced to the two infrared channels (Figure 4, for example) which both show serious noise problems. Because the two infrared channels are noisy, this investigator does not recommend using AIRDAS for producing MODIS test maps.

Although the Ames group that developed AIRDAS claims to have the noise problem solved for the 3.95 µm band, there is no way to correct for the lack of signal at the 10 - 12 µm detector when the mid-IR narrow bandpass filter is in place. This is an unacceptable situation in any event as both channels would be required for fire temperature calculations.

I.3.2 Landsat TM Overview

The Landsat TM is a satellite-borne sensor that consists of 3 visible and 4 infrared bands. For the purposes of this study, only the last three infrared bands (Band 5, 1.55 - 1.75 µm; Band 6, 10.4 - 12.4 microns; Band 7, 2.08 - 2.35 µm) will be used. TM Bands 5, 6, and 7 can be used to simulate MODIS data at the 1.6 µm, 11 µm, and the 2. 1 µm band. After minor modification to adjust the dynamic range of the channels, an algorithm to convert 30m TM data into 1-km MODIS data is applied. This program, developed by Kai Yang at NASA Goddard SFC, takes into account all of the peculiarities of the MODIS sensors.

Landsat TM data is readily availbale for much of the globe. The satellite has a 16-day repeat cycle. Full scenes have much greater instantaneous coverage areas than any airborne intsrument. A full TM scene was acquired over Yellowstone National Park during the 1988 fires which destroyed 1.2 million acres of the park (Morrison, 1992). Figure 4 shows a band 7, 5, and 3 stretch of the part of Yellowstone National Park near Old Faithful (extreme lower left). A firestorm passed over Old Faithful at ~3:30 PM MST on September 7, 1988 (Morrison, 1992). The Landsat TM image was recorded ~19 hours later at ~10:15 PM MST on September 8,1988. In Figure 4, the burn scar from the fires appear brown, while untouched trees are green. Active fires are visible as yellow pixel groups around the edges and near the burn scar. The fires shown are contained within a small 512 x 512 subscene of a much larger (~50,000 x 50,000 pixels) full scene covering the entire area of devastation. Techniques developed for this scene will be applied to the full scene and should provide the first large (1500 km x 1500 km) MODIS Fire data set.

The Landsat TM has a number of drawbacks for studying forest fire temperatures. One is that the dynamic range is not as great as that of the MODIS instrument, resulting in the saturation of many fire pixels. The problem of saturation makes it hard to determine pixel temperatures across the entire range for MODIS channels. The second problem is that TM does not have a channel at 3.95 µm, which is the spectral location of the MODIS Fire channel. In order to use TM as a MODIS data set, a 3.95 µm channel has to be created using data from Bands 5, 6, and 7.

I.3.3 The 3.95 µm Algorithm

The 3.95 µm channel is created using TM bands 5, 6, and 7 of the fire scene. The most accurate estimate of temperatures within a pixel that can be obtained using TM data is the dual-band solution, where two radiative areas at different temperatures are assumed to occupy a given pixel. The three unknowns of the two resultant equations (Matson and Dozier, 1981; Flynn, et al., 1994) are the temperatures of the hot and cool surfaces, and the area of one of those surfaces ([1 - area] is the area of the other surface). Generally, a temperature for the hot surface is assumed (a flaming temperature in this case) and the area that the hot surface occupies, as well as the temperature of the cooler component (perhaps the smoldering area) are solved for.

I.3.4 The 1988 Yellowstone Fire - Statistics of the Old Faithful Fire

I.4 Summary of Results

II. Execution of Proposed Plan

All aspects of the original proposal regarding the SCAR-C deployment were carried out. Data reduction for spectral measurments did take longer than the alotted time in the original proposal. Unfortunately, hyperspectral data were not collected of a prescribed burn as anticipated.

As far as the MODIS fire test maps are concerned, the means to generate these data from TM data were developed in this contract. The MODIS Fire algorithm became available for testing in mid- to late-January and the tests of the algorithm have not been completed at this time. The development of the 3.95 µm algorithm required more time than alotted in the original proposal, but the basic functions and procedures within the algorithm have allowed for the calculation of many fire parameters such as energy density and total energy, which were not part of the original proposal, but will help to evaluate the intensity of fires for other TM data sets. This investigator required some time to become proficient in IDL (Interactive Data Language), an extremely useful tool in regards to image processing which should also help to speed response time for specific requests in future contracts. Lastly, the amount of time to adjust from lava flow to fire problems was not insignificant and was not budgeted in the original contract.

III. Suggested Improvements Future Contracts - Travel

During this contract, two data collection trips were planned to the San Diego area. Both had to be cancelled because the spectrometer was not available. However, the logistics of the trip were particularly difficult because plane tickets and the travel advance were being issued from USRA in Washington, D.C. Denise Dunn at USRA was entirely competetant in her duties as advances and tickets did arrive on time. However, on both occasions, tickets did not arrive until 2 days before the trip. Also, there was no flexibility in changing flight plans (Plans had to be made at least a mmonth in advance). It is very important to be able to chnage flight plans to account for weather, burn possibilities, etc. This investigator can only do this by travelling through the University of Hawaii which uses Hawaii-based travel agents.

There is also a significant savings on the price of airline tickets purchased through Hawaii travel agents. For the Chapman conference, the best fare tthatb the USRA agent could offer was $904 for a Honolulu - Washington, D.C. roundtrip. The best fare through a local travel agent was $620/RT for the same flights. Agents in Hawaii regularly buy bulk tickets from the airlines making their fares less expensive.

Lastly, there is the issue of reimbursement time. A travel completion was filed with USRA in October for the plane fare to SCAR-C only. Reimbursement was received in late January 1995! USRA representatives claim that they are overworked with all of the government travel. The system is not flexible enough for the requirements of this contract. It is suggested that future travel alotments go through the University of Hawaii as a line item in future contracts.

IV. Suggested Course of Action for Next Contract

The follow-on of the SCAR-C project should include analysis of the fires observed during mission operations. While it is important to analyze both wildfires and prescibed burns, the prescribed burns will offer us the most in terms of helpful supporting documentation by field teams including the JPL group with their sun photometers, and more importantly, Roger Ottmar and company of the USFS, who were able to make detailed observations of the fire including estimates of the amount of fuel in the burn area before and after the fire. While any of the prescribed burns in Washington and Oregon would be suitable for study, this investigator suggests that 1 or 2 fires be targeted for careful study in the next year to look at the development of fires. Perhaps the best candidate in the prescribed burns was the Quinault fire (Fig.1) in Washington state. The ER-2 pilot reported seeing the fire being lit, and was overhead before the fire started. He was also still flying overhead when the fire passed through the flaming stage and was well into the smoldering stage.

Because it was very early in the project, supporting crews of Roger Ottmar, Darold Ward, and Peter Hobbs were also on-hand to chronicle the burn. Any radiative temperature measurements calculated will also be important for their efforts to study their data sets. Of the wildfires, all were interesting for the reasons outlined in previous sections. In terms of radiative anomalies, it would be informational to look at the Specimen Creek fire first, since it was overflown on a number of occasions (on separate dates) by the ER-2. According to pilot and USFS reports, this fire was most intense, with strong convection cells above the fire.

The most important aspect of the next contract should be to produce test data for the MODIS Fire algorithm. There are two sources of data for this activity: MAS and AVIRIS data from SCAR-C and TM data of Yellowstone. Since the algorithms already exist, it should be a fairly simple task to convert the Yellowstone data, although the 3.95 µm conversion algorithm can take considerable time to run for large TM scenes. While we have collected plenty of forest fire data (SCAR-C and TM), we are short on data of other vegetation types such as grassland fires. It may not be possible to pick out a large number of data sets to test the Fire algorithm on, but an attempt should be made to identify at least 3 or 4 fuel types that cover a large area of the Earth and test those areas. The TM data could be acquired relatively inexpensively if it was received through the Landsat Pathfinder program.

The University of Hawaii ASD, Inc. spectrometer is currently undergoing extensive testing for a shutter problem. Replacement detectors in the infrared region of the spectrum (1.8 - 2.5 µm) are more senstive than the original design specifications. While this will lead to beter data sets in the future, it means that the instrument is sensitive to radiation out to 2.7 µm. Essentially, the last detector is also sensing heat from the instrument itself which is introducing a noise component in the 1.8 - 2.5 µm range. This problem can be corrected if the drift rate is not significant (i.e. if the instrument quickly reaches an equilibrium operating temperature and then remains at that temperature while it is operational). If it does remain stable, the instrument will be able to measure in the radiance mode accurately with corrections. This will be determined in the next month. It would be very useful to obtain data of a prescribed burn to try to identify threshold.

V. References

Flynn and Mouginis-Mark, 1992
Flynn et al., 1993

Flynn and Mouginis-Mark 1994
Morrision, 1992
Rothery et al. 1988